UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER



**CHEMISTRY** **9701/04**

Paper 4 Structured Questions **May/June 2008**

**1 hour 45 minutes**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do **not** use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

**Section A**
Answer **all** questions.

**Section B**
Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| Total | |

This document consists of **19** printed pages and **1** blank page.

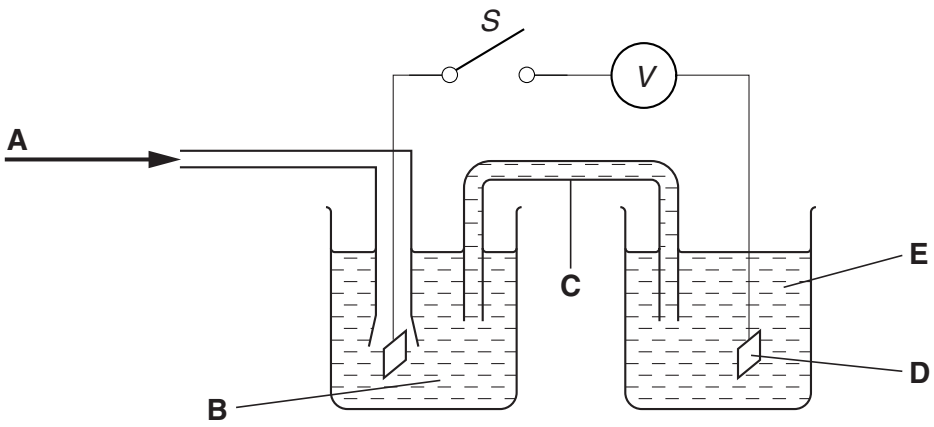
## Section A

Answer **all** questions in the spaces provided.

**1** Chlorine gas and iron(II) ions react together in aqueous solution as follows.

$$Cl_2 + 2Fe^{2+} \longrightarrow 2Cl^- + 2Fe^{3+}$$

**(a)** The following diagram shows the apparatus needed to measure the $E^{\ominus}_{cell}$ for the above reaction.




**(i)** In the spaces below, identify what the five letters **A** – **E** in the above diagram represent.

**A** .....

**B** .....

**C** .....

**D** .....

**E** .....

**(ii)** Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction, and hence decide which direction (left to right, or right to left) electrons would flow through the voltmeter *V* when switch *S* is closed.

$E^{\ominus}_{cell}$ = ..... V

direction of electron flow .....

[7]

**(b)** Iron(III) chloride readily dissolves in water.

$$FeCl_3(s) \rightarrow Fe^{3+}(aq) + 3Cl^-(aq)$$

**(i)** Use the following data to calculate the standard enthalpy change for this process.

| species | $\Delta H_f^\ominus$ / kJ mol$^{-1}$ |
|---|---|
| $FeCl_3(s)$ | –399.5 |
| $Fe^{3+}(aq)$ | –48.5 |
| $Cl^-(aq)$ | –167.2 |

$\Delta H^\ominus$ = .....kJ mol$^{-1}$

**(ii)** A solution of iron(III) chloride is used to dissolve unwanted copper from printed circuit boards.

When a copper-coated printed circuit board is immersed in $FeCl_3(aq)$, the solution turns pale blue.

Suggest an equation for the reaction between copper and iron(III) chloride and use the Data Booklet to calculate the $E^\ominus$ for the reaction.

equation .....

$E^\ominus$ = ..... V
[4]

[Total: 11]

**2** This question is about the properties and reactions of the oxides of some elements in their +4 oxidation state.

**(a)** Chlorine dioxide, $ClO_2$, is an important industrial chemical, used to bleach wood pulp for making paper, and to kill bacteria in water supplies.

However, it is unstable and decomposes into its elements as follows.

$$2ClO_2(g) \rightarrow Cl_2(g) + 2O_2(g)$$

**(i)** The chlorine atom is in the middle of the $ClO_2$ molecule. Using the chlorine-oxygen bond energy as 278 kJ mol$^{-1}$, and other values from the *Data Booklet*, calculate $\Delta H$ for the above reaction.

$\Delta H$ = ..... kJ mol$^{-1}$

**(ii)** Assuming the C*l*-O bonds in chlorine dioxide are double bonds, predict the shape of the $ClO_2$ molecule. Explain your answer.

.....

.....

**(iii)** $ClO_2$ can be made in the laboratory by reacting $KClO_3$ with concentrated $H_2SO_4$. Other products are $K_2SO_4$, $KClO_4$ and $H_2O$.

Construct a balanced equation for this reaction. You may find the use of oxidation numbers helpful.

.....

[5]

**(b)** Sulphur dioxide is an atmospheric pollutant.

**(i)** State **two** sources of atmospheric $SO_2$ that arise from human activity.

.....

.....

**(ii)** Explain why $SO_2$ is a pollutant, and state an environmental consequence of this pollution.

.....

.....

[3]

**(c)** All the oxides of the elements in Group IV in their +4 oxidation state are high melting point solids except $CO_2$.

**(i)** Explain this observation by describing the bonding in $CO_2$, $SiO_2$ and $SnO_2$.

.....

.....

.....

**(ii)** State the difference in the thermal stabilities of $SnO_2$ and $PbO_2$. Illustrate your answer with an equation.

.....

.....

$CO_2$ dissolves in water to form a weakly acidic solution containing the hydrogencarbonate ion.

**(iii)** Write an equation for the reaction of $CO_2$ with water, and write an expression for the equilibrium constant, $K_c$.

.....

.....

**(iv)** Explain the role of the hydrogencarbonate ion in controlling the pH of blood, illustrating your answer with relevant equations.

.....

.....

.....

[7]

[Total: 15]

**3** The elements of Group IV all form tetrachlorides with the general formula $MCl_4$.

**(a)** Draw a diagram of a molecule of $SiCl_4$ stating bond angles.

[2]

**(b)** Describe and explain how the volatilities of the Group IV chlorides vary down the group.

.....

.....

..... [2]

**(c)** The relative stabilities of the $M^{2+}(aq)$ and $M^{4+}(aq)$ ions also vary down Group IV.

**(i)** Use the *Data Booklet* to illustrate this observation when $M$ = Sn and $M$ = Pb.

.....

.....

.....

**(ii)** Use the *Data Booklet* to predict the products formed, and write equations for the reactions occurring, when

- an equimolar mixture of $Sn^{2+}(aq)$ and $Sn^{4+}(aq)$ is added to $I_2(aq)$,

.....

.....

- an equimolar mixture of $Pb^{2+}(aq)$ and $Pb^{4+}(aq)$ is added to $SO_2(aq)$.

.....

.....

[4]

**(d) (i)** The Sn–C*l* bond energy is +315 kJ mol$^{-1}$. Use this and other values from the *Data Booklet* to calculate $\Delta H^{\ominus}$ for the reaction

$$MCl_2(g) + Cl_2(g) \rightarrow MCl_4(g)$$

for the following cases.

- $M$ = Si

$\Delta H^{\ominus}$ = ..... kJ mol$^{-1}$

- $M$ = Sn

$\Delta H^{\ominus}$ = ..... kJ mol$^{-1}$

**(ii)** Do your results agree with the trend in relative stabilities of the +2 and +4 oxidation states in **(c)**? Explain your answer.

.....

.....

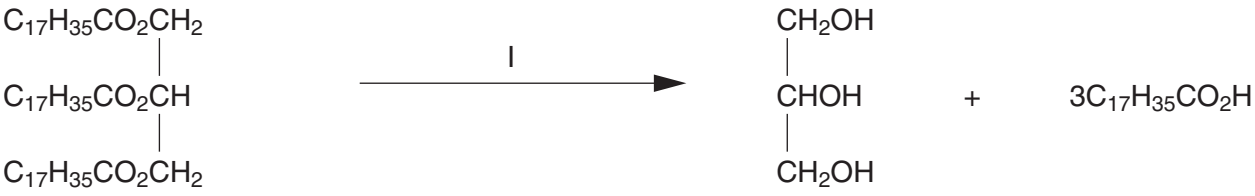
.....

[3]

[Total: 11]

**4** Recently much interest has been shown in the production of the fuel *biodiesel* from algae. Up to 55% of the mass of the dried algae is composed of lipids, the majority of which are triglycerides.

To convert triglycerides into biodiesel, the following processes are carried out.




a triglyceride, $M_r$ = 890

glycerol


biodiesel, $M_r$ = 298

**(a)** Name the functional group present in triglycerides.

..... [1]

**(b)** Suggest reactants and conditions for

reaction I,

.....

reaction II.

.....
[4]

**(c)** Suggest the structural formula of the compound formed when glycerol is reacted with

**(i)** an excess of HBr(aq),

.....

**(ii)** an excess of hot acidified $K_2Cr_2O_7$(aq).

.....
[2]

**(d)** Calculate the mass of biodiesel that can be produced from 1000 kg of dried algae, assuming that 50% of the algal mass is triglycerides.

mass = ..... kg [2]

**(e)** **(i)** Construct an equation for the complete combustion of biodiesel.

.....

**(ii)** Use your equation to calculate the mass of $CO_2$ produced when 10 kg of biodiesel is burned.

.....

.....
[3]

**(f)** The production of biodiesel is at present an expensive process.

Suggest a reason why the development of biodiesel as an alternative to fossil fuels is important.

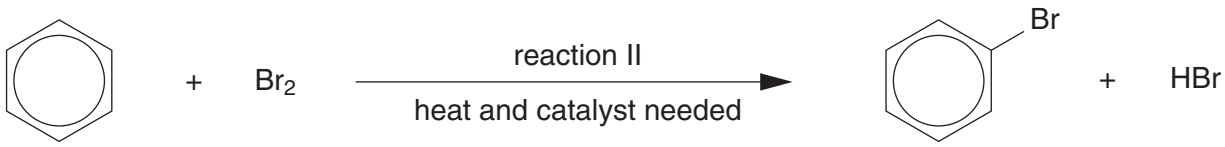
.....

..... [1]

[Total: 13]

**5** Both ethene and benzene react with bromine, but the mechanisms and the types of products of the two reactions are different.

$$H_2C{=}CH_2 + Br_2 \xrightarrow[\text{no heat, no light, no catalyst needed}]{\text{reaction I}} BrCH_2CH_2Br$$




**(a)** State the *type of reaction* undergone in each of reactions I and II.

reaction I

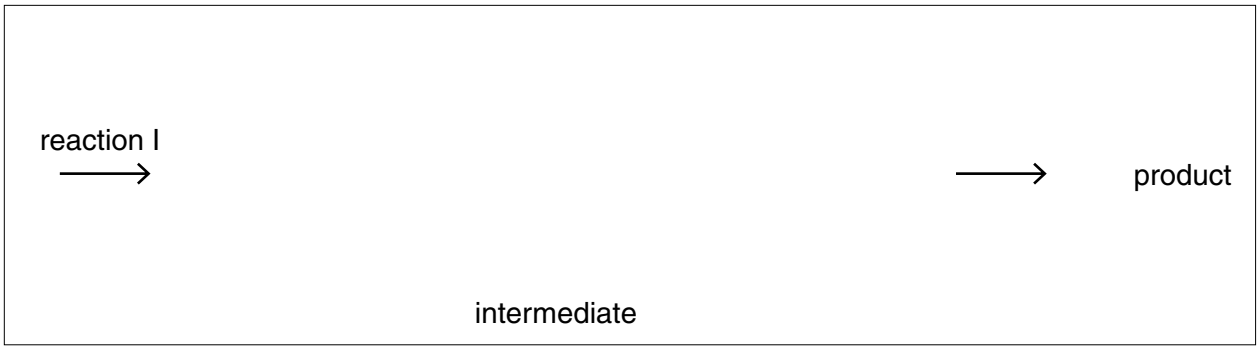
.....

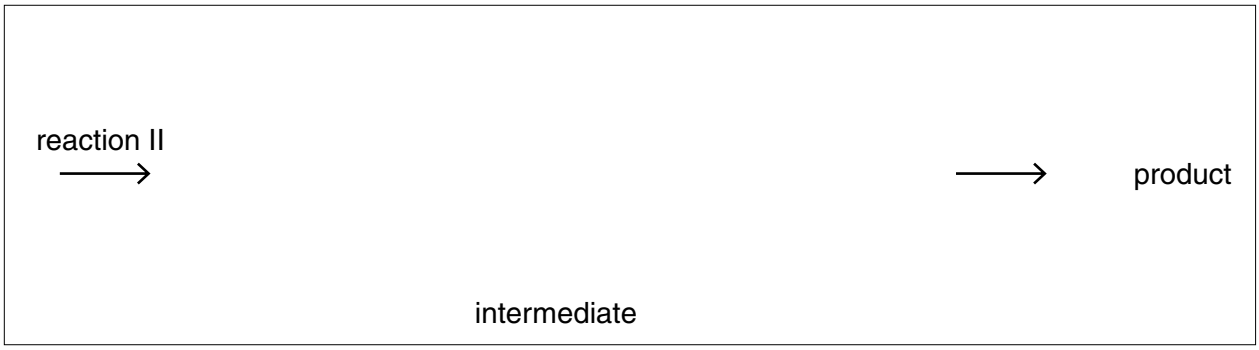
reaction II

.....

[2]

**(b)** In each of reactions I and II, the intermediate is a bromine-containing cation. In each of the following boxes, draw the intermediate and use curly arrows to show how it is converted into the product.



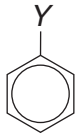

[4]

**(c)** Why do ethene and benzene differ in their reaction with bromine?

.....

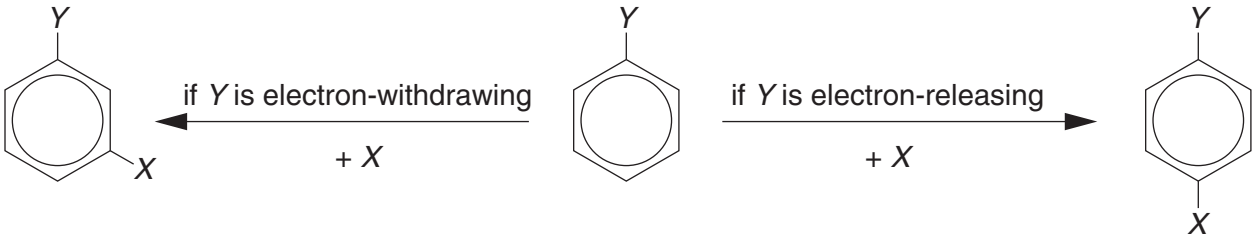
..... [1]

[Total: 7]

**6** The substituted benzene compound  can be further substituted.



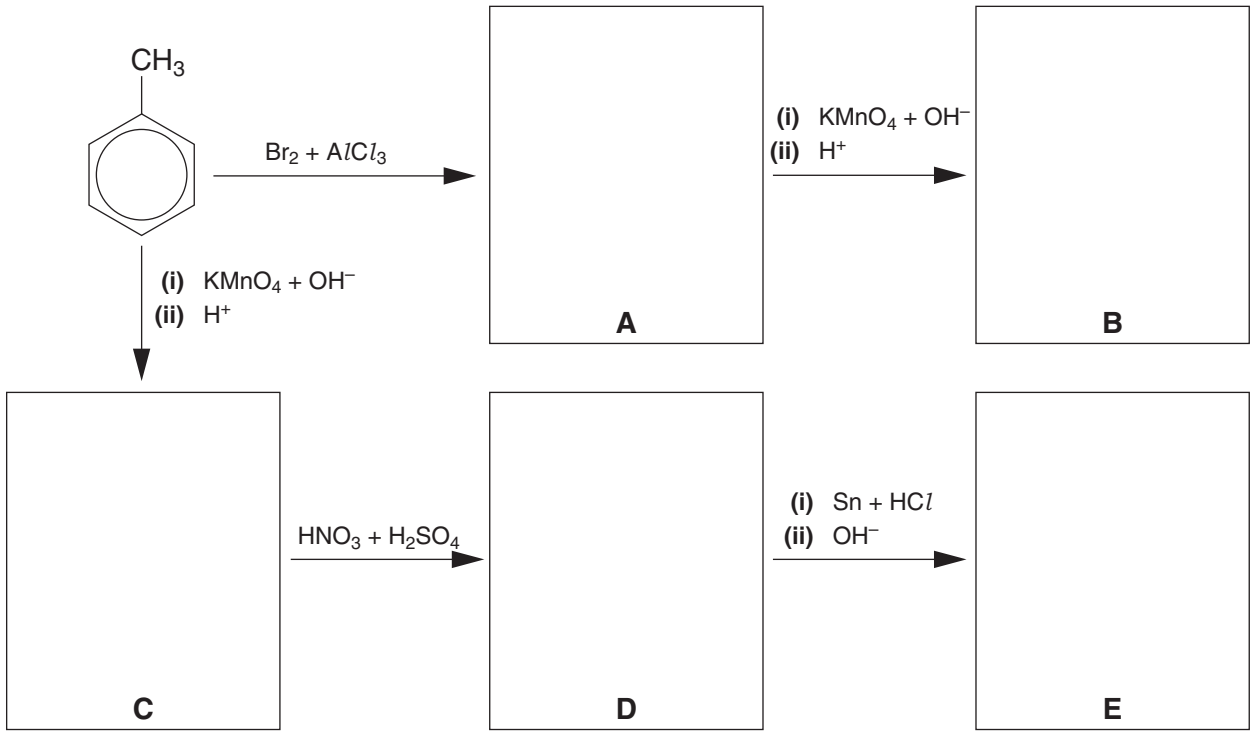
If *Y* is an electron-withdrawing group, the next substitution will be in position 3.
If *Y* is an electron-releasing group, the next substitution will be mostly in position 4.




The following table lists some electron-withdrawing and electron-releasing substituents.

| electron-withdrawing groups | electron-releasing groups |
|---|---|
| $-NO_2$ | $-CH_3$ |
| $-COCH_3$ | $-CH_2Br$ |
| $-CO_2H$ | $-NH_2$ |

Use the above information to draw relevant structural formulae in the boxes in the schemes below.



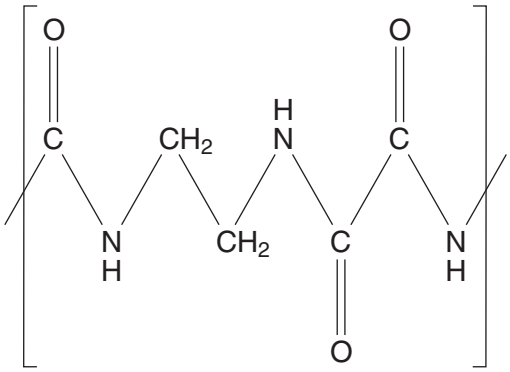
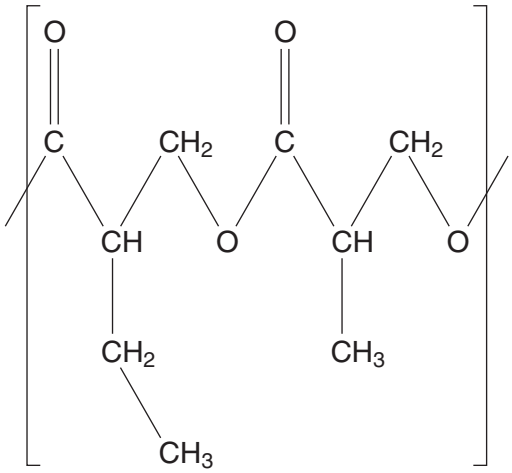
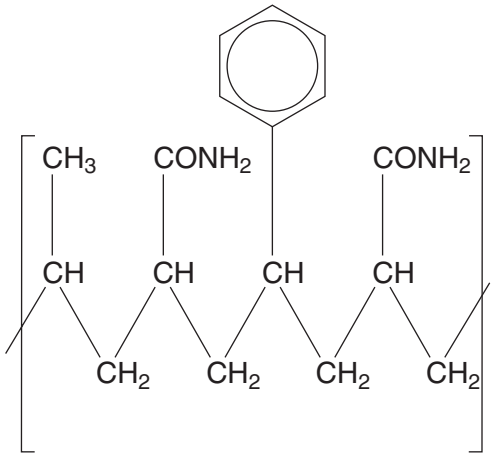

[5]

[Total: 5]

**7** Each of the following structures is an 8-atom segment of the chain of a commercial polymer.

For each structure,

- decide whether it is part of a condensation or an addition polymer, and
- draw the structural formulae of the monomer(s) from which the polymer is made.

| polymer | addition or condensation? | formulae of monomers |
|---|---|---|
|  | | |
|  | | |
|  | | |

[8]

[Total: 8]

## Section B – Applications of Chemistry

Answer **all** questions in the spaces provided.

**8** **(a)** State and show, using suitable diagrams, the types of bonding that occur in the primary, secondary and tertiary structures of a protein.

primary

secondary

tertiary

[6]

**(b)** Analysis of a polypeptide **A** showed that the amino-(N-)terminal end is methionine (met) and that the carboxyl-(C-)terminal end is lysine (lys).

Enzymic hydrolysis of the polypeptide produced the following tripeptides, with the amino acid residue on the left having the free amino group.

met-ala-gly  gly-arg-val  ala-gly-arg  arg-val-lys  ala-gly-ala  gly-ala-gly

Work out the sequence of amino acids in **A**, using the 3-letter abbreviations. Use each tripeptide once only.

[2]

**(c)** Give **two** examples of how interchanging the positions of two amino acids could affect the bonding in, and hence the overall structure of, the protein.

.....

.....

.....

.....

..... [4]

[Total: 12]





[Turn over

**9** Much of the preparation of evidence to solve crimes now relies on instrumental analysis. This question deals with some of the techniques used.

**(a)** Electrophoresis can be used to separate amino acids produced by hydrolysing proteins. The amino acids are placed in a buffered solution in an electric field. In a solution of given pH, what **two** factors affect the movement of a given amino acid?

**(i)** .....

**(ii)** .....

[2]

**(b)** Nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry are also used in the detection of certain molecules, particularly those containing hydrogen atoms.

**(i)** Explain how and why the NMR spectrum of propanal, $CH_3CH_2CHO$, would be different from that of propanone, $CH_3COCH_3$, which contains the same atoms.

.....

.....

.....

.....

.....

**(ii)** Explain how and why the mass spectrum of the two compounds in **(i)** would be different.

.....

.....

.....

.....

.....

[4]

**(c)** At one time, bromomethane, $CH_3Br$, was widely used to control insect pests in agricultural crops and timber. It is now known to break down in the stratosphere and contribute to the destruction of the ozone layer.

Samples can be screened for traces of bromomethane by subjecting them to mass spectrometry.

**(i)** Which peak(s) would show the presence of bromine in the compound?

.....

**(ii)** How could you tell by studying the M and M+2 peaks that the compound contained bromine rather than chlorine?

.....

.....

[3]

[Total: 9]

**10** **(a)** A number of drugs, such as insulin for diabetics, are delivered by injection rather than by mouth (oral delivery). Suggest **two** reasons why this might be necessary.

**(i)** .....

.....

**(ii)** .....

.....

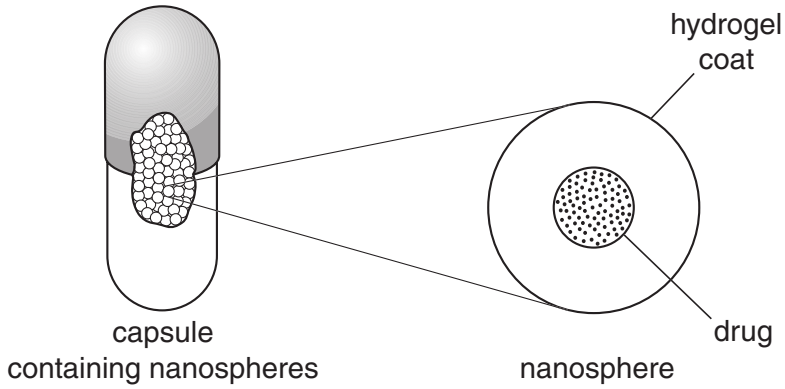
[2]

**(b)** Many patients prefer oral delivery to injection, and a number of methods for overcoming the problems of oral delivery are being investigated. Several of these use nanotechnology.

Study the passage and diagram and then answer the questions that follow.

*At a 2004 meeting, engineers from the University of Texas described their research into nanospheres for oral drug delivery. Nanospheres can transport a drug safely through the hostile environment of the stomach.*

*The nanospheres are created from hydrogels which are stable, organic materials formed from a network of polymer chains. Hydrogels have a variety of uses including disposable nappies, soft contact lenses, dressings for burns and, more recently, drug delivery. The drug is contained in the hydrogel nanosphere as shown in the diagram below. Hydrogels absorb water and swell at a rate dependent on the pH of their environment. As the hydrogel swells, the drug is released.*




**(i)** What is a *nanosphere*?

.....

**(ii)** Suggest why the stomach might be a particularly hostile environment for drugs.

.....

.....

**(iii)** Suggest **two** ways in which the nanosphere shown in the diagram can be modified to change the rate of drug release.

.....

.....

.....

[4]

**(c)** Hydrogels may be formed as homopolymers (using a single monomer), or heteropolymers (using two or more different monomers).

By using the monomers below, you are to draw sections of **both** a homopolymer and a heteropolymer. Each of your drawings should show a three-monomer section of the polymer.

$HOCH_2CH_2OH$ $HO_2CCHRNH_2$ $HO_2CCH(OH)CH_2CO_2H$

homopolymer

heteropolymer

[3]

[Total: 9]

**BLANK PAGE**